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Effect of Inlet Temperature on Pineapple Powder and Banana Milk Powder

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Abstract

Fruits are the main source of fiber which gives great beneficial to human health. Consumption of fruits/fiber are incredibly low among youngsters especially little children. The study focuses on producing fruits and fiber powder as a means for easy transportation, storage and longer shelf life. The objective of this research work are to produce banana milk powder that can help children that suffers from constipation as well as to produce pineapple powder at lower inlet drying temperature. The effect of spray and freeze dryer were studied for banana milk powder, whereas, spray drying method was chosen for producing pineapple powder. The effects of the type of dryers, pump feed speed in the spray dryer and the ratio proportion of the banana milk powder were investigated in the study. The result indicate that increasing proportion ratio of the banana milk powder produced lower yield of the powder. It was also concluded that speed 2 was the ideal condition for banana. Pineapple was found to be dried best at 25% maltodextrin concentration and 150°C as it produced the lowest moisture content at 4%db. Pineapple powder recovered the highest given as 80g at 150°C and 25% concentration of maltodextrin. Particle size of 4.097 micrometer was found to be the finest at the lowest inlet drying temperature at 130°C.

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Keywords: Drying, banana, milk, pineapple.

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1. Introduction

Banana or (*Musa spp.)* is a herbaceous plant of family *Musaceae* that have originated from the tropical region of Southern Asia and throughout the tropic and part of the subtropics. Banana is a climacteric plant that will continue to ripen after harvest. It can be cultivated in hot and wet region that can bear fruit every year and one of the oldest cultivated plant. It can be eaten raw or cooked. The immature banana are in green that will gradually turn to yellow when it's ripe. Banana is well known as a source of carbohydrate and dietary fiber. It also offers great medical benefit to human being as it has enough calcium, nitrogen and phosphorus for the human body to regenerated tissues. It also contains excellent source of vitamins that are listed as below:

a) Vitamin A that aids in healthy teeth, bones, soft tissue, and etc.
b) Vitamin B6 that aids in the body's immune system, promotes brain health, heart health, and etc.
c) Vitamin C that aids in healing, growth of tissue, ligaments, and more
d) Vitamin D that helps to absorb calcium for the body.

The vitamins contain in the banana definitely help in maintaining our health. Banana also contains the best source of potassium which is an important mineral for maintaining normal blood pressure and heart function. According to Kumar, *et al*. (2012) a medium sized banana can provide 350mg potassium that can lower the blood pressure and had been demonstrated by a number of studies. Banana usually can be eaten alone or combined with fruit salads or made into milk shake that can also attract young children eating more fruits. Health care professional stated that banana gives many beneficial to children especially to children with constipation. Banana contains high fiber and can act as a prebiotic to stimulate the growth of friendly bacteria in the bowel movement which help to restore the normal bowel activity without consuming any laxatives. On the other hand, banana also suitable for children that are underweight since it consists of sugar which provides energy. Banana with milk is the most appropriate for the children as it increases weight and also provides enough calcium for their growth of development.

Ananas Comosus is a tropical fruit known as pineapple where it originates from Southern Brazil and Paraguay then, it is then widely spread to the South America. It is the most economically fruit in the *Bromeliaceae* family and in the third rank of world tropical fruit production in 2005 with the annual production of more than 14.6 million tonnes (Aliyu Abdulhammeed Bello, 2012). There are 4 varieties of the pineapple which are Smooth Cayenne, Queen Victoria, Red Spanish and Pernambuco. In Malaysia there are many varieties of pineapple that can be found which are Gandul, N36, Mauritius, Josaphine and Sarawak. According to the nutrition data, pineapple is rich with vitamin C, magnesium, potassium and other mineral. Usually pineapples are used in cuisines, besides it can be consumed fresh, converted into juiced, jam, ice cream and etc. Usually, the carrier agent used for spray drying pineapple is maltodextrin. Maltodextrin is the product of starch hydrolysis that contain the D-glucose units linked by $\alpha(1\rightarrow4)$ glycosidic bonds (Phisut, 2012).The type of carrier agent and their concentration that were used affects the physicochemical properties of the product. The carrier agent also protects the flavor and aromas beside it reduce the volatility and reactivity of the product where it can provide additional attraction.

The production of instant banana milk powder aids parents to provide nutrient drinks to their children. Banana milk is thus converted into banana milk powder. Therefore, spray drying or freeze drying can be applied for this processes it produces longer shelf life products. The final product obtained from these methods may differ in their physicochemical, nutritional properties and microstructure.

Spray dryer converts liquid products into powder by rapid drying with hot gas that had been widely utilized for commercial production of milk, fruit and vegetables (Caparino *et al*., 2012; Kim *et al*., 2009 & Kha *et al*., 2010). Due to its versatility and speed, spray dryer became the most used drying technique. However, there are some issues in the spray dryer production, the dried powder usually contain large amount of simple sugars which may cause stickiness (Ppadakis *et al*., 2007) .The particles intend to stick to one another and to the dryer and remain at the cyclone wall which will further formed thick wall deposits, while very little product comes out at the dryer's exit. On the other hand, freeze drying technique is based on sublimation process where the product is frozen first (Oetjen, 2000). Freeze drying is performed at low temperature and pressure, hence it is suitable for drying heat sensitive products. During freeze drying, the substances are not exposed to high temperatures, therefore the final product suffers little damage caused by thermal or chemical degradation. Thus the freeze-dried products preserve their initial nutritious characteristics. The aim of this research was to investigate the effects of using freeze and spray drying on the quality of the banana milk powder.

The final product (powders) depend on the parameter of the spray drying which are drying agent material, concentration agent material, feed flow rate inlet, outlet air temperature, sticky point temperature and glass transition temperature. The inlet temperature will affect the moisture content of the product, bulk density of the powder, particle size of the powder, hygroscopicity, process yield of the powder, stability of the anthocyanin and morphology.

2. Methodology

2.1. Production of banana milk powder using spray and freeze dryer

In this survey we aim to identify the effects of spray and freeze drying on producing banana milk powder using different drying conditions. The flow diagram of the experimental work is shown in Figure 1 below.

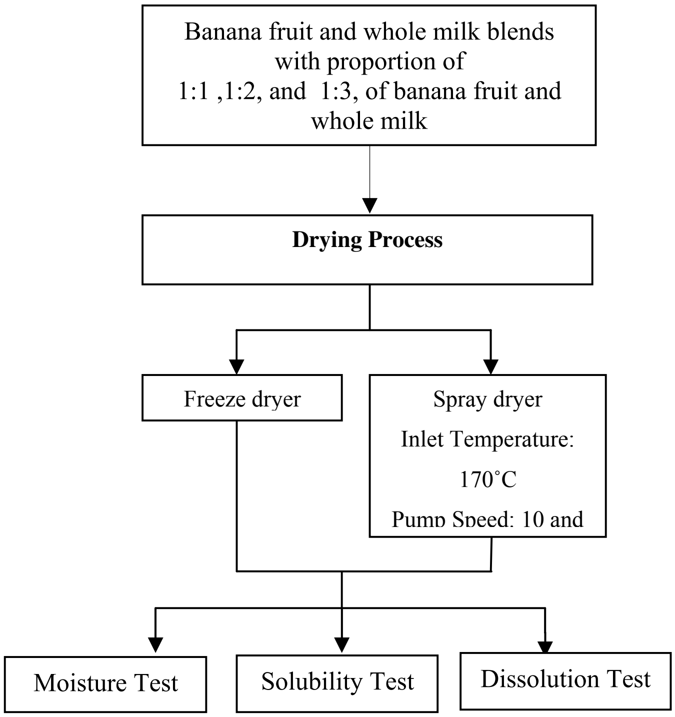

Fig. 1 The flow diagram of the experimental work

Figure 1 shows the flow diagram of the experimental work where the sample of the banana fruits are blend with milk in different proportion which are then tested for its moisture content, solubility and dissolution characteristics.

2.2. Materials and apparatus

SASTEC Freeze Dryer was used in the experiment and it was operated at -65˚C at a vacuum pressure of 1.0 Pascal. The freeze-drying process lasted for 120 hours. Sample are freeze and put into the dryer for about 16 hours. Spray dryer (Basic Lab Plant)was used in the experiment. The inlet temperature was set up to 170˚C .There were two manipulated values for speed of the feed pump which were (2 and 10).The powder produced were collected and weighed

2.3. Physico-chemical analysis of banana milk powder

The powder samples produced during experiments were kept in a dessicator until analysis stage. The powder physical properties measured includes, dryer yield, moisture content, solubility and dissolution.

- Moisture content test

  The moisture content was determined according to Anklam method (Anklam, 1997). Weight of empty dish was initially measured. Three gram of the sample powder were then added into the dish (W_i).The sample was dried at 130˚C for one hour and measured again (W_f).

$$MC_{wb} = \frac{W_i - W_f}{W_i} \quad (1)$$

Where:-

MC_{wb} is moisture content in wet basis (%)

W_i is weight before drying

W_f is weight after drying

- Solubility test

The solubility test was determined according to the Eastman and Moore method (1984) with some modifications. The purpose of this test is to study the performance of a certain amount of powder which can dissolve in water. A 50 mL of distilled water was transferred into a beaker and 1g of the powder sample was carefully added. The mixture was left to operate at high velocity for 5 minutes. An aliquot of supernatant was then transferred and placed to a pre-weight petri dish and dried immediately in an oven at (T=105 ºC for 2 h) .The solubility percentage was calculated by the weight difference.

- Dissolution test

The dissolution test was modified according to Al-Kahtani and Bakri (1990). About 50 mg of sample was dissolved in 1 mL of distilled water and mixed using vortex at half speed. The time for each sample to reconstitute was taken. This step will be repeated for three times.

2.4. Physico-chemical analysis of pineapple powder

The main raw material that used in this experiment is pineapple which is Josaphine pineapple. The pineapple was peeled and cut into a small piece. After that, the small piece of pineapple was crushed into juice by using a blender. The juice that was formed will filtrate with the filter to avoid more pineapple fibrous will formed that will give a problem during the drying process.

The pineapple juice that was formed will be measure for the pH value, colour and soluble contents by pH meter, chromameter and recfractometer respectively. The maltodextrin-pineapple solution was prepare by added the maltodextrin into the 500g of pineapple juice. In order to get the 15%, 20% and 25% of maltodextrin contents, the amount maltodextrin that needs to be added are 75g, 100g and 125g. Then, the solution is stirrer to get the maltodextrin dissolved with the pineapple juice. After the product was recovery, the analysis of product must be made. The analysis that was carried out is powder recovery moisture content, pH value, colour, solubility and particle size. For the product yield simple calculation was made as the ratio of the product should be recovered is 37 g of powder for 137 g of feed.

To analyze the solubility, colour and pH measurement, the powder that was recovered must be added into the distilled water to dissolve it into a solution with the ratio 18.5g of powder: 50g of water. This ratio was based on the average production yield which is the feed 137 g, it could produce 37 g of powder. Then, a magnetic bar was dropped and the beaker was located on the “FISHER” hot plate stirrer model 210T setting at speed 1100 rpm. The stopwatch was started same as the hot plate stirrer started and stopped when the powder in the beaker entirely dissolved. The heater must not to turn on. The measurement was conducted at the room temperature at 25ºC. The recorded time, namely solubility was indicated in the unit of minute. Then, the solution was test by using the pH meter, refractometer and chromameter. For the moisture content, the powder will determined by moisture analyzer. 5 g of powder is put in the moisture analyzer at 105 ºC for 10 minutes. Then take the reading of moisture content at the moisture analyzer. Next for the particle size, the powder was measured by using Malvern particle size analyzer.

3. Results and Discussion

The effects of various parameters, such as blend proportions ratio of milk and banana, feed pump speed, the type of dryer on the relative yield of the resultant powder, moisture content, solubility, dissolution were studied. Considering that they were all responsible for the overall quality of the final dried powder.

3.1 Yield of banana milk powder

The yield of banana milk powder is affected by the type of the dryer, the feed pump speed used and the blend feed ratio of milk banana proportion. Loss of product in a spray dryer may occurred during drying due to the sticking of the particle solution around the drying chamber. Figure 2 shows the product produced using freeze drying at 1:3 proportion. Dried powder cannot be produced using freeze dry at this proportion since most of the product was freeze at the wall of the flask. This may be due to high solid content of the liquid mixture being used to dry in the freeze dryer

It is showed that the blend proportion of 1M:1B in the spray dryer has the highest yield compared to other proportions. This is because the solid content is lower than the other sample solution. From Figure 2,it is also showed that the yield of the powder production decrease as the speed of the feed pump increases. The higher the feed flow rate will cause part of the feed passed straight to the chamber without sufficient time of atomization resulting in a higher of process waste and a lower process yield. According to Phisut,N.,(2012) at constant atomizer speed and increased feed pump flow will cause more liquid atomized into the chamber and thus reduced drying time. Hence, drying will be incorrect.

3.2 Moisture content analysis

Moisture analysis was test to identify the amount of the water content in the powder. The moisture content is important since it can keep the quality of the powder. High moisture content will decrease the quality of the product since it lower down the activity of bacteria in the food product. Figure 3 shows the percentage of moisture content of the product after drying. The results showed that at constant pump feed speed 2 and freeze dryer , the moisture content is increases as solid content increases. In a spray dryer the water content of the feed will affect the final moisture content of the powder produced. Higher proportion of banana increases the total solid content and thus reduces the amount of water evaporation. Hence, it will increase the moisture content of the powder produced. This also means that powders with higher moisture content could be obtained by increasing the proportion of the banana in the feed flow rate. Freeze dryer on the hand shows the total opposite from the theory explained for spray dryer. It is shown that, as the amount of banana increases in the feed flow rate, the moisture content of the dried powder decreases rapidly. For the proportion of 1M:3B, moisture content analysis could not be done as the dried product could not be obtained as it stick inside the drying chamber of the freeze dryer.

3.2 Solubility Analysis

The solubility of most powdered food are essential as rehydration process will occur when the dried milk powder comes into contact with water. A good rehydration process will wet the dried powder quickly and it will dissolve without lump or float in the solution.From Figure 4, it is shown that the highest percentage solubility is at the ratio of 1M:1B at every speed for spray dryer and decreased with the increase of the banana content. This may cause from the solid content that dissolve in the solution. Higher solid content of the sample decreases the solubility of the powder to dissolved in the water. From the Figure 4 it is shown that highest percentage solubility is for speed 10 in the spray dryer.From the figure it also shown that the solubility of the powder for freeze dryer are much lower than in the spray dryer.

3.1 The comparison of the properties between the fresh pineapple juice and pineapple powder

There are many factors that can affect the properties of the dried pineapple such as inlet temperature, air flow rate, feed flow rate, atomizer speed, types of carrier agent and their concentration are influencing as particle size, bulk density, moisture content, yield and hygroscopicity in spray dried foods (G.R. Chegini, 2007).

Table 1 shows that the comparison between the fresh pineapple juice and the pineapple powder at the different inlet temperature and different MD content %. For the optimum condition, normally the inlet temperature that used for spray drying process for food powder is 150-220^{o}C. Referring to Table 1, the soluble solid content of the pineapple is higher than the fresh pineapple juice. The soluble solid content is increase as the addition of the maltodextrin in the sample (Phisut, 2012). The solid soluble content of the pineapple powder does not depend on the inlet temperature as there does not have a constant trend of increasing or decreasing solid soluble content as the inlet temperature increase (J.Sci, 2009).

Besides that, the the pH of the pineapple powder is higher than the fresh pineapple juice. The increasing of the pH value for each experiment is not constant but the increasing of the pH value is because the addition of the concentration maltodextrin into the sample which the maltodextrin pH is 4.7 (J.Sci, 2009). Referring to Table 1, the colour appearance, the lightness, redness and yellowness of the pineapple powder is more lightness, redness and yellowish compare to fresh fruit juice for each experiment. This is because the sample was exposed during the spray drying process and non-enzymatic browning reaction occurring during the spray drying

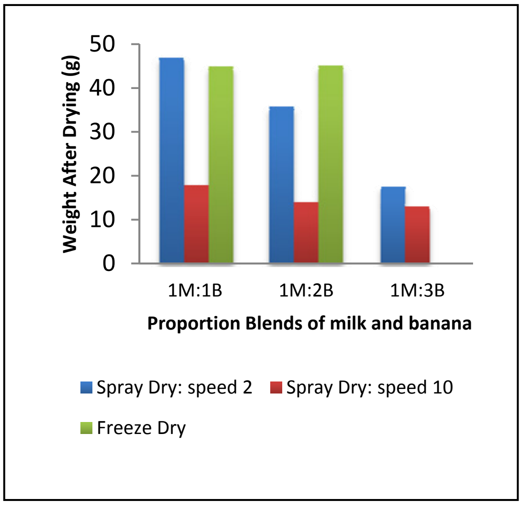

Figure 2: Weight after drying for banana milk

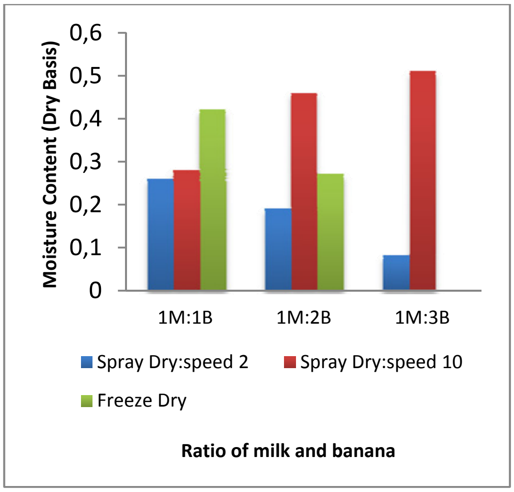

Figure 3: Moisture content plot for banana milk

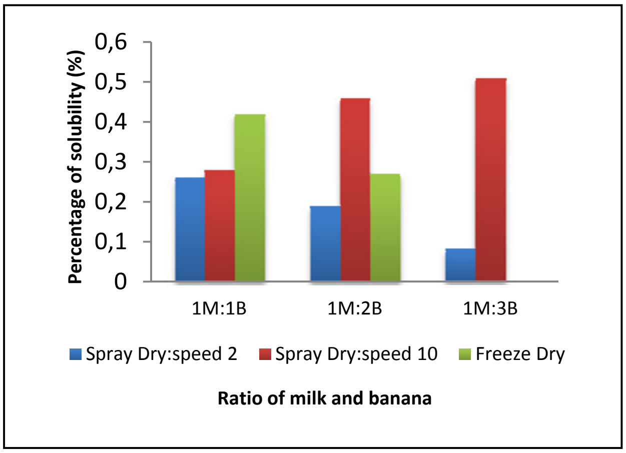

Figure 4: Solubility plot for banana milk powder

Table 1: The comparison of the properties between the fresh pineapple juice and pineapple powder

Inlet temperature (ºC)	MD content (%)	Fresh fruit juice					Juice from the pineapple powder				
		Soluble solid content	pH value	Colour			Soluble solid content	pH value	Colour		
				L*	a*	b*			L*	a*	b*
130	15	1.34115	3.85	26.31	-2.30	5.52	1.37238	3.90	31.99	-1.46	13.29
	20	1.34144	3.98	25.94	-2.17	5.28	1.37310	4.00	28.83	-1.62	6.53
	25	1.34177	4.10	25.68	-2.20	5.68	1.37287	4.26	27.53	-1.85	7.44
140	15	1.34126	3.85	26.47	-2.40	5.73	1.37293	3.94	27.52	-2.01	6.83
	20	1.34265	3.95	25.36	-2.91	6.47	1.37558	4.07	28.16	-2.17	8.93
	25	1.34706	4.18	24.80	-2.70	6.23	1.376281	4.23	26.98	-1.38	8.09
150	15	1.34372	4.15	28.50	-2.87	7.65	1.375410	4.32	29.86	-2.69	11.77
	20	1.34613	4.14	28.15	-3.36	9.89	1.37579	4.20	34.27	-2.87	18.12

	25	1.34339	4.18	24.80	-2.70	6.23	1.37700	4.23	26.98	-1.38	8.09

3.2 The effect of inlet temperature on moisture content of pineapple powder

Figure 5 shows the comparison of moisture content (%) for each temperature at the different concentration of maltodextrin. The moisture content will decreased by increase the inlet drying temperature. This is due to the faster heat transfer between the product and drying air. The higher inlet air temperatures, the greater temperature gradient between the atomized feed and drying air and it will give the greatest driving force for water evaporation (Phisut, 2012). Inlet air temperature also can affect the hygroscopicity of the powder. Hygroscopicity is capacity of the powder to absorb ambient moisture. The powders that produced at higher inlet temperature are more hygroscopic compare to the lower inlet temperature. This is because of the moisture content presence in the powder and also the water concentration gradient between the product and the surrounding air (Phisut, 2012).

3.3 The effect of inlet temperature on the solubility of the pineapple powder

For the solubility of the pineapple powder, the effect of the inlet temperature is unclear but the solubility of the pineapple powder is decrease if the concentration of the maltodextrin is increase (J.Sci, 2009). The solubility of the pineapple powder depends on the concentration of the maltodextrin where the increasing the concentration of maltodextrin could reduce the hygroscopicity of the powder which is shown in Figure 6. The lower the hygroscopicity will confirm it efficiency of the carrier agent. Then, as a result the solubility of the powder will decrease (increase in value of solubility in seconds) (Phisut, 2012). Besides that, the higher glass transition temperature of the powder will decrease the hydroscopy, increase the melting point and lower water solubility. As a result, low sticky product will be produced during the spray drying process (J.Sci, 2009).

3.4 The effect of inlet temperature on the powder recovery

Process yield also can be affected by the inlet temperatures where the higher inlet temperatures, the higher process yield. Process yield is related to the efficiency of heat and mass transfer processes occurring during the process spray drying. The higher inlet air temperatures were used, the greater efficiency of heat and mass transfer processes would be. But sometimes, the increasing of inlet air temperature can reduced the yield due to the melting of the powder and cohesion wall. Therefore the amount of powder production also reduced (G.R. Chegini, 2007).

Figure 7 shows that the higher the inlet temperature at the same concentration of maltodextrin, the amount of powder recovery will increase but there are also the amount of powder recovery is reduced as the higher inlet temperature. It is also shown that, at the constant the concentration of maltodextrin at 20% of maltodextrin, the powder recovery is reduced.

3.5 The effect of inlet temperature on the particle size of the pineapple powder

Besides that, the inlet temperature can affects the bulk density of powder. The increasing of inlet air temperature will give a result in a rapid formation of dried layer on the droplet surface. Furthermore, it can cause the particle size change beside the skinning over or casehardening on the droplets at the higher temperatures. This process leads to the formation of vapor-impermeable films on the droplet surface followed by the formation of vapor bubbles and the droplet expansion (Chegini, 2005).

Generally, the increase of drying air temperature causes the decrease in bulk, particle density and provides the greater tendency to the particles to hollow. The particle size is one of the parameters that can be affected by inlet temperature. The higher inlet air temperature will leads to the production of larger particles and causes the higher swelling. Higher inlet temperatures will faster the drying rates where it can cause the formation of a structure and it did not allow the particles to shrink during drying. When the inlet air temperature is low, the particle remains more shrunk and smaller. The rapid formation of dried layer at the droplet surface causes the skin hardened and did not allow the moisture to exit from the droplet (Phisut, 2012). Table 2 shows that the higher inlet air temperature, the larger size particles of the powder that produced.

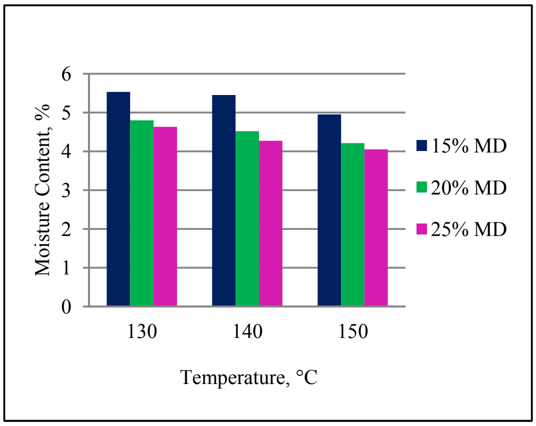

Figure 5: Moisture content plot for pineapple powder

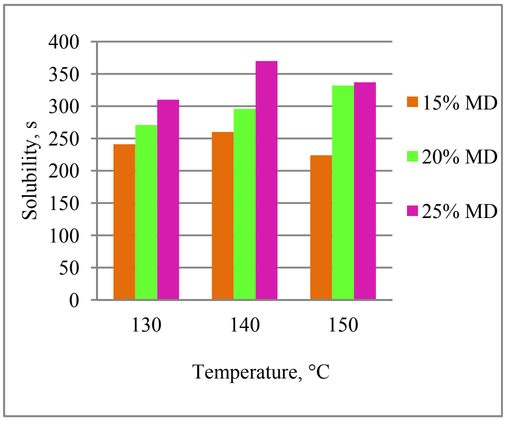

Figure 6: Solubility plot for pineapple powder

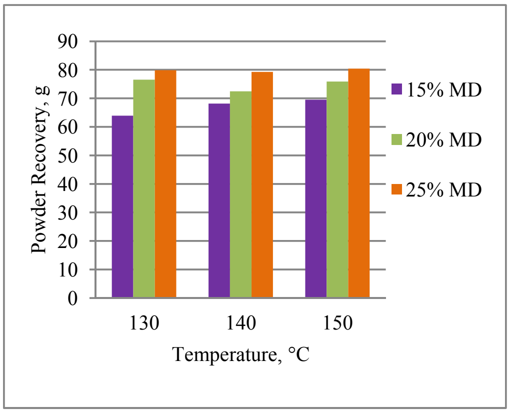

Figure 7: Powder recovery plot for pineapple powder

Table 2: Particle size of pineapple powder

Inlet temperature (°C)	Maltodextrin content (%)	Particle size (µm)
130	15	4.097
	20	5.724
	25	874.328
140	15	6.694
	20	643.774
	25	941.445
150	15	12.706
	20	924.647
	25	1025.86

4. Conclusion

The results obtained confirm that different drying techniques givestrong impact to the powder quality. Among the blends with different levels of banana milk, the blend with a 1M:1B ratio of milk and banana at speed 2 was found to bethe desirable powder as it shows the best condition for the physico-chemical analysis in the spray dryer .The optimum condition for the spray dryer was found to be at temperature of 170˚C and speed 2.Since the moisture content of the powder (Temperature = 170˚C , speed 2) was the lowestamong all of the other spray-dried and freeze drier powders. It is then taken to be the best conditon for the dried powder. As a conclusion the inlet temperature in *Ananas Comosus* for optimum condition can affect the moisture content of the product, bulk density of the powder, particle size of the powder, hygroscopicity, process yield of the powder, stability of the anthocyanin and morphology

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